ENGINEERING

MINISTRY OF FINANCE.

SURVEY DEPARTMENT.

PRELIMINARY NOTE

ON THE

SUBSOIL WATER IN LOWER EGYPT

AND ITS BEARING ON THE REPORTED DETERIORATION OF THE COTTON CROP.

BY

H. T. FERRAR, M.A., F.G.S.

Presented to the Cotton Commission.

Price 50 Milliemes.

CAIRO:

NATIONAL PRINTING DEPARTMENT,

1910.

MINISTRY OF FINANCE.

SURVEY DEPARTMENT.

PRELIMINARY NOTE

ON THE

SUBSOIL WATER IN LOWER EGYPT

AND ITS BEARING ON THE REPORTED DETERIORATION OF THE COTTON CROP.

BY

H. T. FERRAR, M.A., F.G.S.

Presented to the Cotton Commission.

Price 50 Milliemes.

CAIRO:

NATIONAL PRINTING DEPARTMENT,

1910.

LIST OF ILLUSTRATIONS

(AT END).

COVERING NOTE

TO

MR. H. T. FERRAR'S PRELIMINARY REPORT ON THE MOVEMENT OF THE SUBSOIL WATER IN LOWER EGYPT AND ITS BEARING ON THE REPORTED DETERIORATION OF THE COTTON CROP.

As requested by the Secretary-General of the Khedivial Agricultural Society, I have the honour to submit the attached note by Mr. H. T. Ferrar on the experimental investigation into the movement of the subsoil or underground water now being carried out by him by means of series of tube-wells in the vicinity of Rahebein, Shinraq, and Santa (see sketch-map enclosed).

It was not intended to publish the results of the experiments being at present conducted in the Delta until the measurements had been carried out for a somewhat more protracted period and had been supplemented by further measurements in other localities, as it was felt that any conclusions upon a question affecting so important an issue as cotton culture in Egypt should be arrived at only after a very thorough examination of all available sources of information and after a very careful scrutiny of the evidence procured. It is accordingly with some reluctance that the attached preliminary note is submitted, for, although it is believed that the conclusions arrived at are sound and will be endorsed by further experiments, yet it is felt that much more complete investigation is required before anything in the nature of final deductions can be drawn or resulting action taken.

Turning now to the Note itself, it must first of all be remembered that it is extremely difficult within the compass of a small note, necessarily hastily compiled, for Mr. Ferrar to give anything like an adequate presentation of the subject, and altogether impossible for him to include complete data or full explanations or references.

There is one other point on which a few words of warning should, perhaps, be added. Mr. Ferrar indicates the existence of two water-tables in the Delta (see diagram), one due to the hydrostatic pressure caused by the Nile and such other waterways as tap the sands underlying the Delta alluvium, and the other due to water entering the alluvium itself, either laterally by seepage from canals or water-channels, or vertically by being poured on to the surface of the land in watering. The first is called the natural water-table, and the second the artificial, and as would be expected, in some places they are superimposed and the combined effect only is apparent,

The effect of what is called the natural water-table may be dismissed as almost wholly innocuous to cultivation, and therefore calls for no immediate comment here.

The artificial water-table (except in the immediate vicinity of the river at high-stage) is wholly the result, in one way or another, of the water brought into contact with the upper layers of the alluvium for the purposes of cultivation. It cannot be doubted that in this way high-level canals have a deleterious effect on the strips of land immediately bordering them, but it must also be remembered that the harmful effect of such a canal alone in water-logging the crops cannot extend far laterally, provided the neighbouring land is not either abnormally low-lying or abnormally porous. On the other hand, a similar and undoubtedly more widespread, though possibly locally less injurious effect is due (*a*) to the numerous small *misqas* which interlace the country in every direction, and (*b*) to the water which is poured on the land itself in the process of watering crops. In the former connexion, it must be remembered that some form of distributory canal is a necessity to enable cultivation to be carried on at all, and that such canals cannot be made water-tight; that if such distributory canals are run at a higher level than the surrounding country, they afford a simple and economical means of providing flush-irrigation to rich and poor alike; that the damage undoubtedly caused by such high-level canals to adjacent land is probably susceptible of material mitigation if proper precautions are taken; that the price thus paid for the economy and convenience of general flush-irrigation may ultimately be found not to be too high; and, finally, that any alteration involving such a radical change in the existing irrigation system as the abolition of all canals running above the level of the country would entail enormous expenditure and could hardly be entertained until it was certain that the accruing advantages would be both certain and large.

Further, even if the use of high-level canals was abolished, and lift-irrigation adopted from all the main feeders, yet the use of flush-irrigation must be ultimately resorted to in the case of the numerous *misqas* already referred to which conduct the water about the surface of the land. The regulation of the amount of water in these *misqas* and of that poured on the surface of the ground in watering, is in the hands of the cultivators themselves, and it would appear premature for the State to inaugurate any radical alteration in the existing irrigation system involving large expenditure, until an attempt has been made to induce cultivators in general to use with greater judgment the water brought to the margins of their fields.

The same remarks apply, although to a lesser extent, to the provision of a huge network of public drains. There is no room to doubt that drainage is badly required throughout the country, but drains do not necessarily imply drainage and the provision of the most elaborate system of public drains would be of comparatively little advantage unless each cultivator undertook himself to pay attention to the drainage of his land in the same way as he at present does to the watering of it, and it need hardly be pointed out that the simplest preliminary

step is to reduce the amount of water applied to the surface and consequently to minimize the quantity which has eventually to be drained off.

No attempt has been made by Mr. Ferrar, except incidentally, to analyse the effect of the subsoil water-levels upon the cotton plant; nor, if the deleterious nature of this be admitted, of its relative importance in comparison with other hurtful agencies, as the consideration of neither of these falls within the scope of his note.

It should perhaps also be explained here that when Mr. Ferrar says that the water-table has been raised, he refers, except where otherwise stated, to the formation of what is called the artificial water-table and not to the increase in the height of the latter itself, although he believes that this has also occurred.

In conclusion, it is desired to request the Commission to take into consideration the necessarily tentative nature of the conclusions brought forward, owing to the investigation being as yet only in its preliminary stages, it having even been impossible as yet to attempt an interpretation of a great many of the measurements taken. It is hoped, by following up steadily the lines of enquiry which are now becoming apparent, that considerably further light will be thrown upon the problem under consideration.

E. M. Dowson,
Director-General,
Survey Department.

Giza, March 8, 1910.

PRELIMINARY NOTE

ON THE

SUBSOIL WATER IN LOWER EGYPT, AND ITS BEARING ON THE REPORTED DETERIORATION OF THE COTTON CROP.

Water is known to occur beneath all land, whether it be cultivated or desert, prairie-land or mountain. This water is spoken of as subsoil or underground water, and is regarded as primarily due to rainfall upon the surface of the earth. The geological conditions under which this underground water occurs, have made it convenient to classify underground sources under the heads : surface, artesian, and deep-seated. The subsoil or underground water of Egypt is derived from the Nile, and belongs to the first category, although the deep wells of this country are often erroneously spoken of as being artesian. This error arises because the comparatively impermeable layer of alluvium, known as the Nile mud, covers a great series of porous sands and gravels which are permanently saturated, and yield a ready supply of water when tapped by a deep well. It has been proved that this underground water is a single and finite body, and that its upper surface rises and falls annually according to the rise and fall of the Nile.

In addition to this natural source of underground water, there is also an artificial supply which passes beneath the soil-surface from canals, great and small,* and from the watered fields. Occasionally these two waters mingle and their upper surface forms the so-called water-table. When, as usual, the Nile alluvium is very dense and impermeable, or of great thickness, these two aqueous zones are kept apart, and by having wells suitably placed, it is possible to study their movements individually.

---

* *i.e.*, irrigation channels of all classes, including private *misqas*.

The accompanying diagram shows how a deep well (No. 13) may be independent of the quantity of water which is applied to the land; how a shallow well (No. 32) may be governed by the natural Nile-flood pressure; how the water-levels in some wells (No. 14 and No. 19) depend upon the artificial application of water; and lastly, how the levels in other wells (No. 36 and No. 35) depend upon the level of the water carried in an adjacent canal.

All this water, from whatsoever source, which is found beneath the surface of the soil, is known as subsoil water, and the following notes will show its bearing on the question of cotton cultivation in Egypt.

The accompanying sketch-map (1 : 50,000, NE. V, I; NE. VI, I) shows the three localities, Rahebein, Shinraq and Santa, where experimental tube-wells have been set up. These are of two kinds, deep and shallow, and they have been placed in lines as nearly as possible at right angles to canals.

An almost complete cycle of observations on the annual fluctuation of the water-table has been obtained at each locality. Diagrams and wells given as illustrations are typical examples, and not specially selected with a view to this report.

Three years continuous work lead me to believe that the average level of the water-table is higher than formerly,* and that it rises to an abnormal height, which is a source of danger to the cotton plant when maturing. It seems probable that these phenomena are among the chief causes which have given rise to a continually decreasing yield of cotton. It is fully recognized that there are other causes at work, such as insect pests, and the primitive methods of sowing and cultivation (cf. photographs Nos. 1^e and 7^f),† but these harmful factors must differ in degree of intensity according to the conditions ruling in the various districts, and cannot of themselves explain why the diminished yield has been so uniform as it is believed to have been throughout the country. The opinions which are expressed in the following paragraphs are only tentative, and must be supplemented by a further series of observations in other districts, and on more complete lines, before any definite conclusions can be stated.

* This refers both to the creation of the artificial water-table and also to the raising of its level in recent years.

† It was not possible to reproduce in this Note the photographs referred to. Prints have been supplied to the Commission.

With regard to the suggestion that the subsoil water is perhaps the factor which is most harmful to cotton cultivation as a whole, we have the following points to consider :—

I. The present higher position of the water-table, due to:—

(*a*) Watering in excess.

(*b*) Seepage from high-level canals.

(*c*) Absence and inefficiency of drains.

II. The raising of the already high water-table at a critical period, due to :—

(*a*) Watering in excess.

(*b*) Seepage from high-level canals.

(*c*) Extra permeability of the soil in certain places.

III. The deterioration of the soil due to increased evaporation from the surface consequent on a high water-table, with resulting deposition of salts.

I.—The present higher position of the water-table.

The curves on the accompanying diagram have been plotted from the results of some of the observations carried out for the Survey Department during the year 1909, and illustrate the fluctuations of the water in a few of the Lower Egypt experimental tube-wells. The water-levels shown on the diagram are all reduced to mean sea-level datum with the exception of the superimposed Nile-flood curve which was plotted without reference to any datum line.

The curve of deep well No. 13 is not influenced by seepage nor by artificial application of water, and as it is similar to the curves obtained from other deep wells, it is concluded that the water-heights here shown are due to the natural hydrostatic pressure of the Nile-flood. For the first seven months of the calendar year, the water-heights in the shallow tube-wells are higher than those obtaining in this deep well, and this difference of the level proves that the water-table has been raised artificially. Towards the end of the month of July, the water in all the wells approaches a minimum level, and the extra heights shown by the water-levels in the shallow wells, at this minimum water-table epoch, may be taken as a measure of the extent to which the water-table has been raised artificially. At well No. 14, it can be seen that the water-table has been artificially raised about a metre, and at wells No. 19 and No. 35, about a metre and a half.

Like results have been obtained from all the other experimental tube-wells, and by studying their idiosyncrasies, it appears that the present higher position of the water-table is due to watering in excess, seepage from high-level canals, and absence and inefficiency of drains.

(a) *Watering in excess.*

Well No. 14 is situated in a bean-field, and well No. 19 in an adjacent cotton-field, and both are removed some distance from supply canals. Water-table diagrams show that the water-plane here is nearly horizontal, which points to excessive watering as the prime factor in maintaining the subsoil water at an unnaturally high level, for seepage generally gives rise to an inclined water-table.

(b) *Seepage from high-level canals.*

Water-table diagrams which have been constructed with the aid of measurements made at a number of tube-wells near the Ganabia el Qorashia canal, show that the water-plane slopes rapidly downwards away from this canal, and consequently prove that seepage here is active. To the eastward of this high-level canal and respectively fifty and one hundred metres distant from it, are wells No. 36 and No. 35, which are fifty metres apart. On referring to the diagram, it will be seen that the water-heights in these two wells follow the levels attained by the water in the canal, and that the water-table here has been raised permanently nearly two metres by seepage.

(c) *Absence and inefficiency of drains.*

If the water-table is dangerously high, it is hardly necessary to point out that some form of drainage would alleviate the conditions. The action of existing drains in reducing the present higher position of the water-table is sometimes so local as to be almost negligible. Thus a line of tube-wells set up in order to find what was the breadth of land which received benefit from a certain drain (the Mohit No. 1 at Rahebein, cf. photograph No. 10[b]), showed that it influenced only that portion of the water-table situated within a distance of 65 metres on each side of it. In some parts of Lower Egypt, what may be called *intercepting* ditches or drains are excavated close alongside

canals in order to prevent the seepage water passing transversely beneath the fields. These *intercepting* ditches are, as a rule, not very efficient, for water (less than a metre below soil-level) is very often left lying in them all the year round, although they are in some cases graded to drain into supply channels (cf. photographs No. 8[a] and No. 6[b]).

Survey Department Paper No. 19, now in the press, describes subsoil water investigations carried out by myself in Upper Egypt during the year 1908. In this report the above conclusions have been anticipated, and it is pointed out that, although the action of individual canals and drains is not great, yet the water-table in the provinces of Minia and Beni Suef has been raised permanently nearly four metres by watering in excess and by seepage from perennial canals.

II.—The raising of the already high water-table at a critical period.

It occurs repeatedly that the prospects of the cotton crop are reported good until the month of August, and that during the month of September the probability of a smaller yield than was expected becomes evident, and this disappointing change in the prospects has been attributed to the elevation of the subsoil water-levels. The data which are being collected prove that the subsoil water rises rapidly during these two months. The natural rise directly due to the increased height of the Nile when in flood, does not have any deleterious effect, for the water-levels in the shallow wells are independent of the flood-pressure until the end of September. The plotted curves show that watering in excess, seepage from canals, and the extra permeability of the soil in places are the main factors which raise the water-level and tend to produce asphyxiation of the longer roots of the cotton plants at this critical stage of their development.

(a) *Watering in excess.*

The curves of the water-heights in wells No. 14 and No. 19 are typical of many other curves which have been plotted during the past year, and as we have seen, their water-heights are governed by the water which is applied to the surface of the land. The water in well No. 14 rose more than a metre subsequent to the heavy watering the

land received early in August, and remained high until the land received a second flooding towards the end of September, which saturated the soil from top to bottom. As the curve of this well crosses that of deep well No. 13, we conclude that this artificial water-table would have sunk lower during September, had it not been buoyed up by the natural rise of the subsoil water due to the Nile-flood. The water in well No. 19 shows a small rise at the time it should be approaching a minimum position, and a great rise in August, when the natural water-table had risen only a metre above its lowest position. The curve of this well crosses that of deep well No. 13, twice, as if the water in it were endeavouring to assume a lower and more stable position. These are two, among many examples which have been obtained, which show that the present higher position of the water-table is increased by watering in excess at a time of the year which coincides with what is believed to be the first appearance of deterioration of the plants.

Many cultivators state that the greatest boll-shedding takes place immediately after the first flood-water has reached their fields, but it has yet to be proved whether this increased boll-shedding is due to the first rush of flood-water disturbing the root absorption of the plants, to the sudden rising of the subsoil water, or to other causes. A cultivator, who owns land to the north of Mehalla el Kubra, informed the writer that he gave his cotton only seven light waterings before the first flood-water arrived, but that his neighbours watered their land some twenty-one times, and that while his cotton yielded 5½ kantars per feddan, that of his neighbours gave only one-third to half a kantar per feddan. This statement is in keeping with those of other observers, and goes to show that watering in excess has a multiple deleterious effect upon the cotton crop.

(b) *Seepage from canals.*

The curves of the wells No. 36 and No. 35, show that the water-table rises suddenly at the beginning of the month of August, and rises again to a still higher level about the 20th of September. These sudden rises are due to the increased seepage brought about by the increased volume of water carried by the canal at this period. It has yet to e proved how much orholittlew b the cotton crop is affected by

a fluctuating water-table, or by a sudden rise in the level of the subsoil water, but it is at any rate evident that upward movements due to seepage take place at a time when the lint is being ripened.

(c) *Extra permeability of the soil in places.*

The curve obtained from the shallow well No. 32 shows how a sandy soil may allow the water-table to rise at a period which is critical in the growth of the cotton plant. The rise of a metre shown by this well-water during the month of August cannot be very harmful to the cotton grown above, for the water does not come within a metre of the soil-surface, but other wells in the immediate vicinity show a corresponding rise which is superimposed upon the already elevated water-table, and this extra rise cannot be beneficial to the crop.

It has been pointed out by Sir William Willcocks * that black clayey soils are injured very slowly by infiltration. This statement is illustrated by comparing the behaviour of the water in a deep well, and a shallow well, both of which are in a dense soil. At deep well No. 13, the soil surface is separated from a porous sand-bed by 13 metres of dense black unctuous clay. The plotted curve obtained from this well does not show the natural fluctuation of the Nile infiltration water, for the tube-well, by piercing the impermeable clay, provides an almost frictionless channel in which the hydrostatic pressure of the subsoil water is measured. A curve obtained from the shallow well D. No. 8 in a similar soil, shows that the resistance to movement offered by a dense clay has a damping effect of more than one metre. These facts, coupled with the diminishing yield which has been obtained from dense soils of late years, prove that impermeability, by resisting natural underdrainage, favours the elevation of the water-table at a critical period.

III.—The deterioration of the soil due to evaporation.

Attention has again and again been called to the fact that the soil will deteriorate if the water-table be raised by a too lavish supply of water.† Such deterioration has taken place in America and elsewhere, and now may be seen taking place in Egypt. Everywhere in Lower

---

* "Egyptian Irrigation," Chap. VI, p. 173. 1899.

† Op. cit.

Egypt a traveller may see long tracts of land, parallel to a canal or railway borrow-pit, which support only a stunted crop or often no crop whatever. Sometimes this stretch of land shows itself to be saline, by the crumbly or powdery nature of the plough-furrows (cf. photograph No. 4[e]); sometimes a salt efflorescence appears as a glaring white patch upon the landscape.

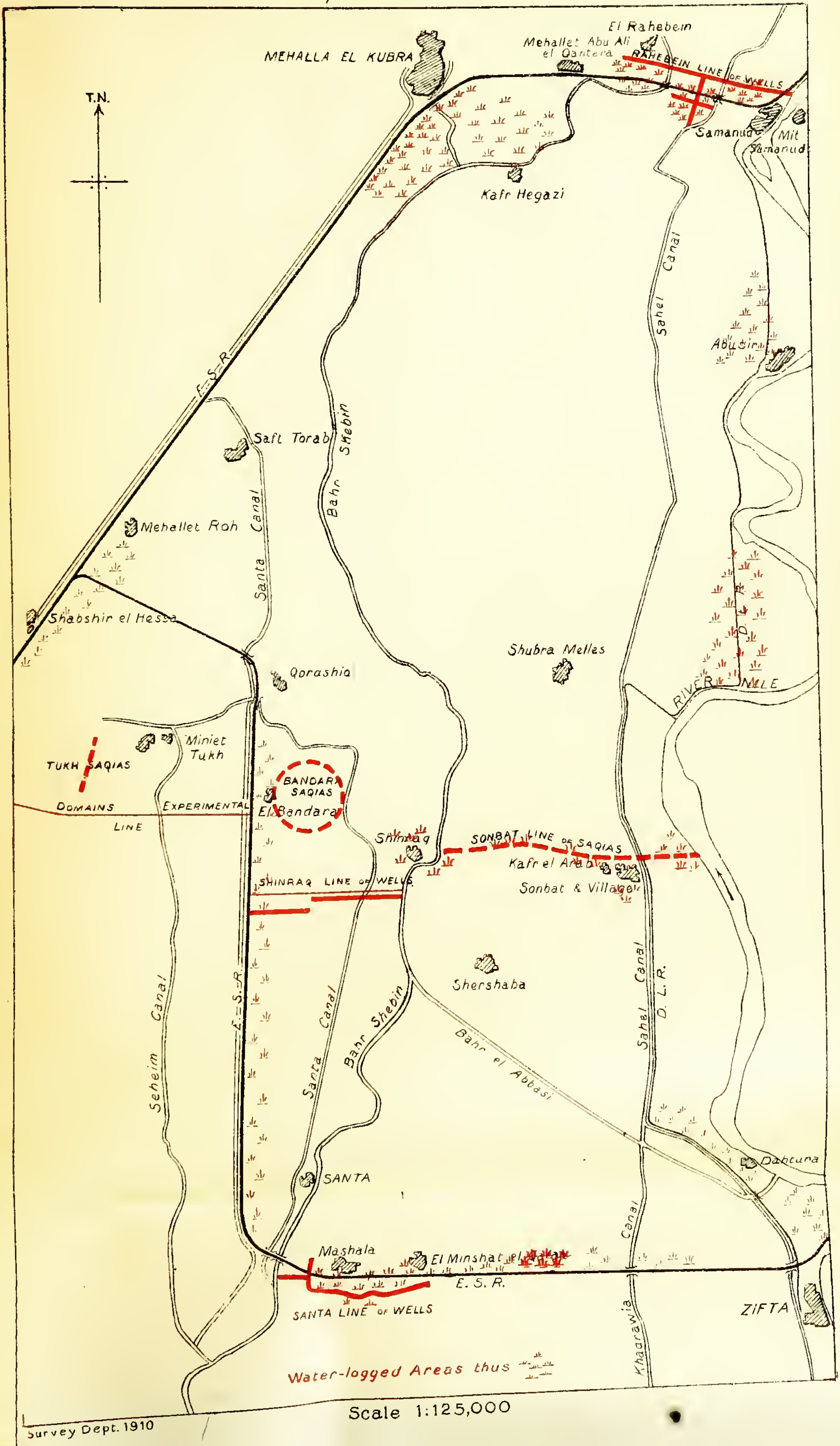
In many parts of both Upper and Lower Egypt, the water in canals and ditches is held permanently at a high level (cf. photograph No. 7[d]), and parallel to them are stretches of barren land, parts of which are in sodden condition, as well as pools of clear brown water in which stand dead and dying crops (cf. photograph No. 6[g]). These facts prove that seepage, by elevating the water-table, is instrumental in causing a deterioration of the soil. The proportion of inferior land which exists in Egypt shows that this evil is widespread and worthy of attention.

Overwatering is another factor which gives rise to a deterioration of the soil, apart from its action in raising the water-table. Many fields are watered by their owners at short intervals, and the continual evaporation from the ever damp soil causes an accumulation of salts at the surface. This salinity is made manifest by the growth of yellow or immature crops, and is apparent at certain times of the year as a white dust on the unploughed field.

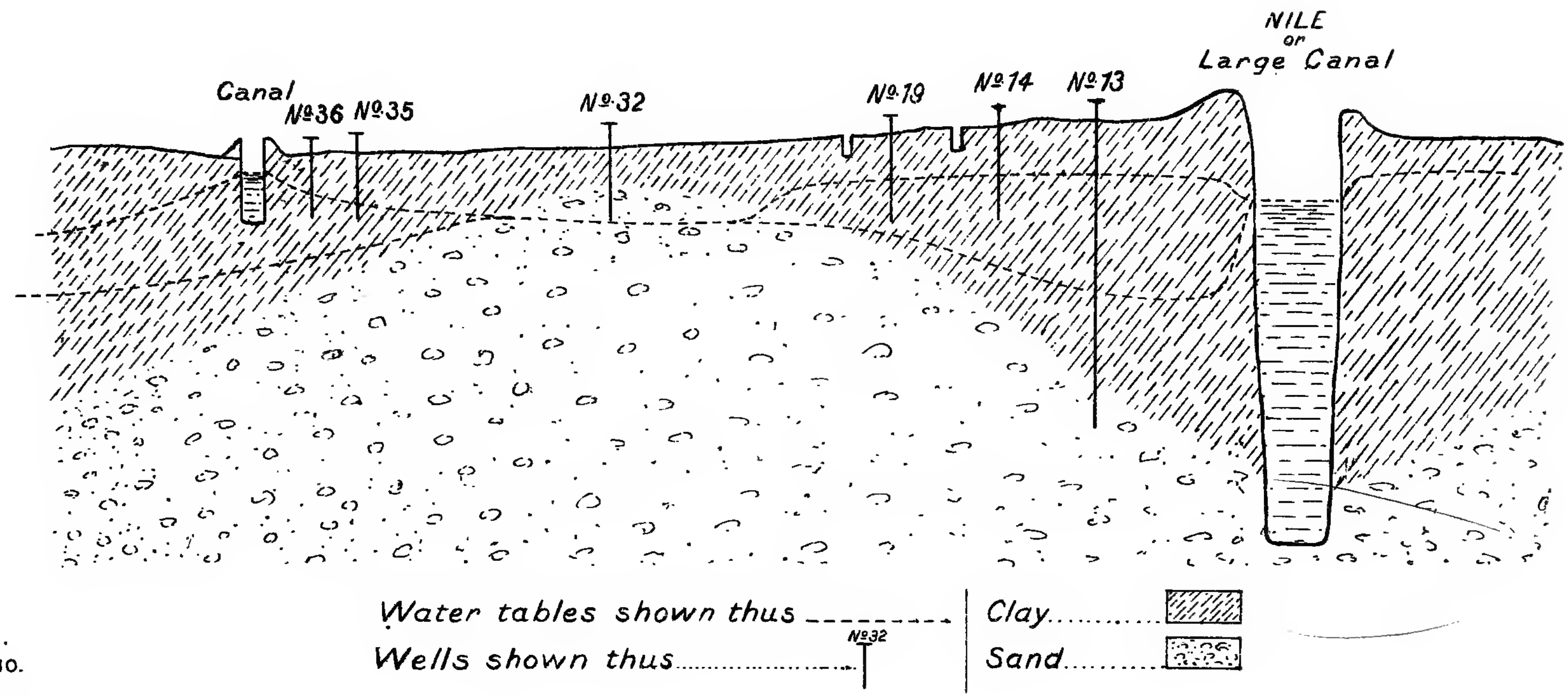
In concluding these notes, I should like to repeat that the opinions expressed are only tentative, and that the subsoil water investigation is being continued on the same general lines, and is also being expanded along such lines of enquiry as the investigation itself brings up. I expect to obtain shortly some data bearing on the lowering of the water-table brought about during January by the closure of the canals for clearance and the consequent cessation both of watering and seepage. The first results to hand show that the emptying of the canals is quickly followed by a reduction in the level of the water-table in the district, and the completed observations are expected to confirm this, and perhaps indicate the lines along which the present conditions might be ameliorated.

Imp. Nat. 1640-1910-100 br.

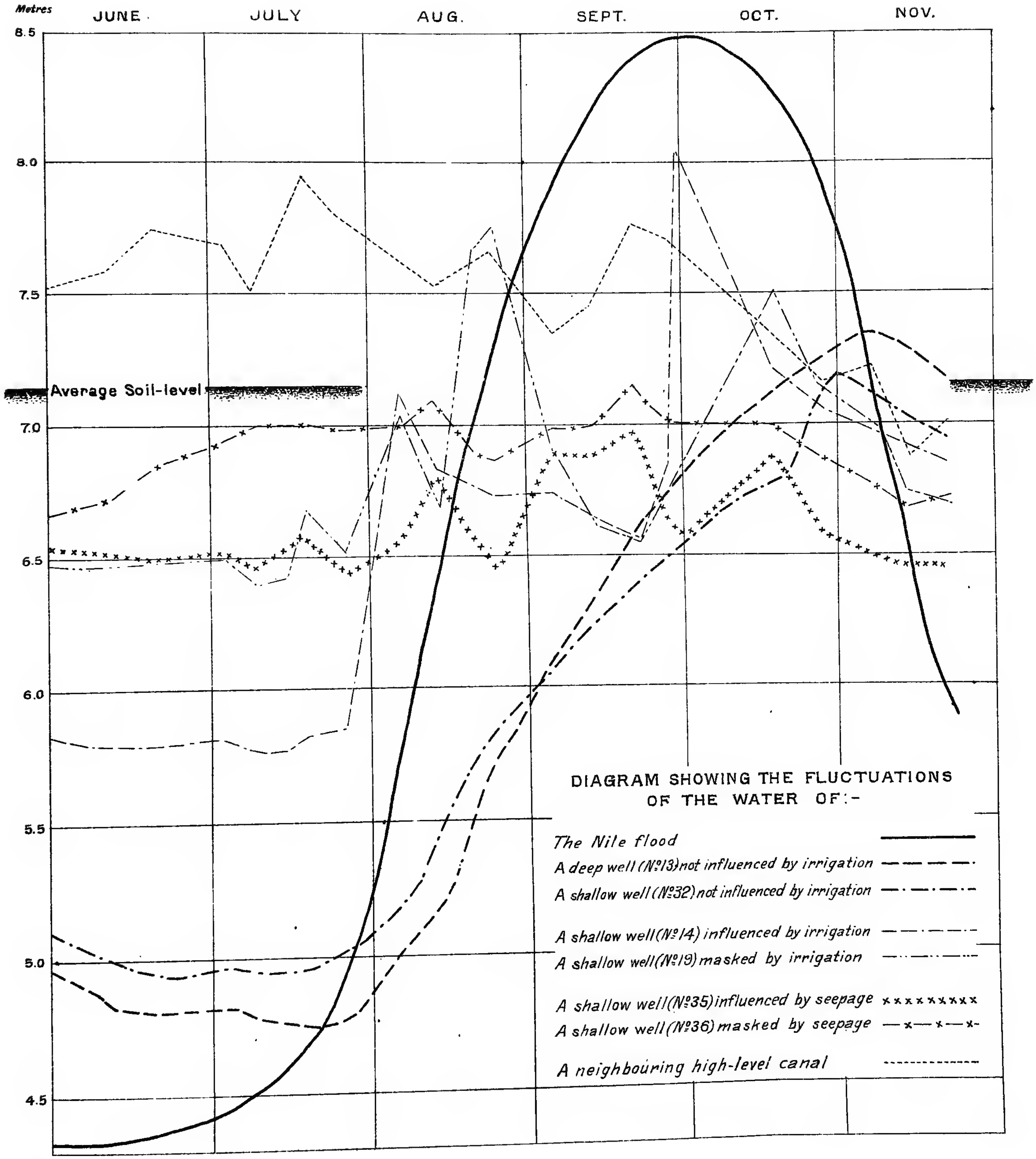
Sketch Map showing positions of Lines of Experimental tube-wells.



Sketch of Cross section of a portion of the Delta illustrating the two Water Tables.



Survey Dept., 1910.


Metres
JUNE.
JULY
AUG.
SEPT.
OCT.
NOV.
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
Average Soil-level
DIAGRAM SHOWING THE FLUCTUATIONS OF THE WATER OF:-
The Nile flood
A deep well (No. 13) not influenced by irrigation
A shallow well (No. 32) not influenced by irrigation
A shallow well (No. 14) influenced by irrigation
A shallow well (No. 19) masked by irrigation
A shallow well (No. 35) influenced by seepage
A shallow well (No. 36) masked by seepage
A neighbouring high-level canal